DESCRIPTIONS...

NUTRITION

Good nutrition is essential to a healthy and active lifestyle. It is important to get the proper nutrients and eat the right amount of calories. Calories are a measurement of energy, and any calories that are not used are stored in the body (usually as fat). Our body weight is determined by the balance between caloric intake and caloric output. Therefore, body weight is determined by how much we eat and how much we use up.

Healthy weight depends on body frame, physical activities, and basal metabolic rate. Basal metabolic rate (BMR) is the rate at which a person burns calories while resting. If you have been told you have a high metabolism, that is like saying you have a high BMR.

A high body weight does not necessarily mean an unhealthy body weight. In fact, low body weights can be unhealthy too. Low body weight can lead to abdominal pain, constipation, weakness, heart arrhythmias, low red and white blood cell counts, weakened bones, and irregular menstrual cycle in females. However, if you have a high body weight due to body fat, that is a risk factor that can lead to health problems including: heart disease, type II diabetes, high cholesterol, high blood pressure, and cancer.

When it comes to body weight, body composition, or what the body is made of, is more important. A person with a high body weight, but low body fat percentage, may mean he or she has a high muscle mass. A lifestyle that includes a diet high in fruits and vegetables with moderate amounts of meat and carbohydrates plus regular exercise is a great way to maintain a healthy body weight.

MATH – SCIENTIFIC NOTATION, RATIOS, PERCENTAGE, ESTIMATION

Math is an extremely important part of science. Numbers are used frequently to record data and explain details about experiments. In some sciences, the numbers used can be very large or small so scientific notation is used. Scientific notation uses powers of ten to express numerical values by placing a decimal after the left-most non-zero number and multiplying by the appropriate power of ten. For example, the number 530,000,000 would be represented as 5.3×10^8. If you count the numbers from where the decimal is in 530,000,000. to just before the five (5), you will find that there are eight (8) numbers giving us 10^8.

Now, if 500,000,000 was the amount of cells after a period of growth that may seem like quite a bit. We really do not know unless we compare 500,000,000 cells with the number of cells before the period of growth. This is where ratios and percentages come in handy. If there were 300,000,000 cells (3.0×10^8) prior to growth, we see a ratio of 3:5, or a three-to-five ratio from before growth to after growth. Since these are both the same power of ten, we can cancel out the 10^8. How many more cells are there? 200,000,000 (2.0×10^8) cells. What was the increase? 2.0 divided by 3.0 is 0.67 or, multiplied by one-hundred, 67% more cells present. We read the symbol "%" as "percent." How many cents in a dollar? There are one-hundred cents in a dollar. "*Giving it 100%*" is giving your all because there are one-hundred percent in a whole just like there are one-hundred cents in a whole dollar. If there is a 33% increase in growth from 3.0×10^8 cells, we want to multiply 3.0×10^8 by 33% or 0.33. Add that number back to 3.0×10^8 cells to find out how many there would be.

Estimation is also very important. With large numbers or quick decisions, it is always good to check our math by estimation. A single number can be estimated by rounding to the nearest 10, 100, 1000, all depending upon the scale. This gives us a number that is wrong, but close, and not to be used for final answers. Let us look at multiplying rounded numbers. If we are multiplying numbers that are rounded, the amount of error in our answer will also be multiplied. Again, this is okay for getting a quick guess, but when needing a final answer, accuracy and precision are more important than speed. What if we needed to estimate how much carpet is needed for a bedroom? We can measure out the room to be 19 feet by 11 feet. Nineteen (19) is close to twenty (20) and eleven (11) is close to ten (10). Twenty (20) multiplied by ten (10) is 200. What is the real answer? Check it out. It is pretty close. By what percent is the estimate wrong?

CHEMISTRY – REACTIONS AND ENERGY TRANSFER

There are many types of reactions that I have to keep in mind to conduct cell research. Concepts that I learned in school are used every day in my laboratory. For example, the law of conservation of mass states that matter cannot be created or destroyed in an isolated system. If liquid, chemicals, and nutrients, known as the culture medium, are put into a bioreactor with cells, even though the cells consume the nutrients, the mass does not change within the bioreactor. However, the bioreactor system can get too acidic or basic based on the contents so we have to understand acids and bases. Cells use oxygen (O_2) and form carbon dioxide (CO_2). If too much carbon dioxide (CO_2) builds up, the system can get acidic and stop the growth, or "culturing" of cells. One way to prevent the solution from getting too acidic is by using buffers. Buffers help to maintain a tolerable acid/base level, or "pH."

Acids and bases are just one area of chemical reactions. We also have to understand the difference between chemical and physical changes in other reactions. Acids and bases can cause chemical changes where substances actually change in their structure. Combustion, or burning, also causes chemical changes. Chemical changes among elements can be quite similar. A Russian scientist with a good first name, Dmitri Mendeleev (1834-1907), recognized the patterns of reactions that elements have and put them into a table to show their commonalities and differences. This was the first periodic table of elements.

Physical changes occur when a substance maintains the same composition but acts differently. For example, heating a solid can change it to a liquid and then to a gas. The substance does not change in its structure but the form, or phase that it takes is quite different. Creating sawdust from a piece of wood is primarily a physical change. However, sometimes wood gets hot enough to burn a little bit. For the most part, the chemical structure of the wood is still intact in the sawdust. Chemical reactions and energy transfers are exciting topics in school and continue to be for me now, especially studying them in the environments of Space and simulated microgravity.

MATH – RATIOS, TABLES, FRACTIONS, AND ALGEBRA

In engineering, I use ratios, tables, fractions, and algebra to solve problems and interpret data given from other engineers and scientists. Ratios are used when I read technical drawings to show the scale of an object. You may see a scaling ratio on the box of a model car or airplane. If the ratio says one inch on the model equals twelve (12) inches on the true object, you know that you have to multiply any length on the model by twelve (12). Scaling ratios are also used on maps to tell distances. Two (2) inches may equal 75 miles. If you want to see how far 2.5 inches on the map equals, use ratios. The scale is 2 inches / 75 miles which will be equivalent to 2.5 inches / x, where "x" is the unknown distance. Cross-multiply and solve for x.

Some problems I solve involve multiplying fractions. Fractions can be multiplied by multiplying the top numbers, the numerators, and writing that number on the top of a fraction. Then, multiply the denominators, the bottom numbers, and write that answer on the bottom of the fraction. To see how to do this graphically, check out the animation.

Reading tables is a common part of my job. It is not too difficult and, therefore, it is a great way to arrange and present information. I just look at the headings for the information that I need. I also keep in mind that columns are positioned up and down, like columns on a building. Rows are oriented left to right like the rows of a movie theater.

Multiplying and dividing are used daily in engineering and science. We already talked about multiplying fractions. Often, I am presented with a problem that uses a formula. Fractions may or may not be involved. Formulas that solve for a variable with two or more terms are known as polynomials. These equations may include variables like time, velocity, distance, mass, among many others. Algebra is a great tool. Practice it often and do not give up on the difficult problems. Everyone finds a difficult problem at some point, but by solving it, you can make your mind that much more prepared for others. After a while, take a look back on the problems that you once found difficult. You will probably be surprised how easy they seem now!

BIOLOGY – SPACE RESEARCH

Cells are the basic unit of life. Understanding what cells do in altered environments gives us a better picture of how entire organisms will respond to similar changes. Space cell biology has just that aim. Growing, or "culturing" cells in space allows them the opportunity to float in the free-fall environment of spaceflight. Cells communicate with one another by attaching to each other. As they float, they have all sides available for this communication which is similar to growth within the body.

If cells are grown on earth, in contrast, gravity holds them down in a Petri dish or T-flask. They tend to grow more two-dimensionally. Allowing cells to float promotes them to grow into the next level of organization, tissue. However, cells grow so well that the inner cells are unable to receive nutrients. In a living multicellular organism, the circulatory system provides nutrients to cells through vessels. This is one of the obstacles we face in culturing cells into tissue-like aggregates.

While they grow in bioreactors, cells create waste which must be monitored and exchanged. Bioreactors are monitored with sensors to detect increasing levels of CO_2, lactate, and other wastes. Bioreactors can have their medium exchanged manually with sterile syringes or with a perfusing system that feeds new medium while it removes it.

Growing single-celled organisms in space, such as bacteria, has also shown that they become more hardy, more virulent or destructive, and grow faster. A disease such as salmonellosis, caused by *Salmonella*, affects the digestive system and could be much more harmful to astronauts if contracted in space. Similarly, cancer is more prolific in space. Studying these changes in space opens up research that has not been seen on earth and may allow for mind-altering perceptions of how bacteria and cancer attack other living cells.

While some cells grow more actively, others have much more difficulty. Cells that are promoted in space are said to have an adaptation for space. One study to determine what types of cells succeed in microgravity used a single-celled organism, yeast, with variations of their genes to detect which genes will and will not survive. This study, among many others, is opening up a completely new understanding of cell biology. Space research is an entirely new horizon of scientific study with much, much more left to discover.

PHYSIOLOGY

The human body reacts to the environment of spaceflight in many ways. The study of the biological and medical effects of organisms in spaceflight is known as "Bioastronautics." This is the area of study that I practice. The body is very adaptive, but some adaptations in spaceflight lead to potential problems upon returning to earth and the 1g (gravity on earth's surface) environment. Preventing these changes or preparations for them are known as "countermeasures."

For example, the skeletal system feels the 1g environment every day, from conception through adulthood. Our bones are stimulated to grow from holding up our own weight against the force of gravity. This is called "loading." When this loading is removed in microgravity, the free-fall environment of spaceflight, bones are not stimulated in the same way. On average, astronauts lose about 1% of their bone mass per month while on orbit. Muscles get weaker and astronauts often experience muscular atrophy. A countermeasure for these two issues is to exercise at least two (2) hours each day while in space.

Everything experiences microgravity while on orbit so astronauts can move very massive objects without much effort. Muscles and bones do not need to work as hard and neither do the heart and lungs. As a result, the cardiovascular and respiratory systems can get weaker on orbit as well. It is most important to have good cardiovascular health on earth as well as in space which is promoted by exercise.

One thing that exercise cannot help with is the sense of balance. The vestibular system is an amazingly designed structure on each side of the head in the middle ear regions. It can tell if the body is changing in speed and direction, moving up or down or to the side. However, the vestibular system uses gravity for part of its analysis. Without the effects of gravity in spaceflight, the vestibular system has difficulty providing direction, orientation, and balance. An astronaut may feel very dizzy for a couple days. This can also cause nausea which can be a big issue when performing an EVA (extravehicular activity), or space walk.

Studies that are being performed in space are providing benefits to people on earth and to those who may travel to the moon or Mars. Much still needs to be understood, but there is proof positive that space research provides a unique window of understanding.

BIOLOGY - ORGANELLES

The cell is an amazing city of life! The cell biology research that is performed here at NASA gives us a better understanding of how cells work in general. Using the bioreactor, we can study both eukaryotic and prokaryotic cells. Before we learn about the difference in eukaryotes and prokaryotes, let us talk about cells in general. Cells are the main building block of life and vary in size, shape, and purpose. They contain many components that each perform their own tasks. Components of cells are called “organelles” and include: mitochondrion, nucleolus, nucleus, endoplasmic reticulum, Golgi apparatus, and cytoskeleton, among many others.

The nucleus is the control center of the cell and holds the chromosomes. Chromosomes hold information about the cell and how to create cells and proteins. The nucleus controls the protein production of the cell by sending out messages to the ribosomes. Ribosomes perform the construction of parts that will become proteins. Ribosomes may work independently floating through the cell, or they can be attached to the endoplasmic reticulum. There are both a rough and a smooth endoplasmic reticulum (ER). The Rough ER is so named because of the attached ribosomes that make it look bumpy. The ER is a factory that makes the proteins, hormones, and other chemicals for the body.

Some proteins made by the ER are sent to the Golgi apparatus which packages and ships them out of the cell through the cell membrane. The cell membrane surrounds the entire cell and controls the passage of anything into or out of the cell. Similarly, a nuclear envelop controls the passage of things into and out of the nucleus. Some cells, however, do not have a defined nucleus with a nuclear envelop. These are called “prokaryotes” versus “eukaryotes” which do have a nucleus.

Movement of the cell is controlled by the cytoskeleton. The cytoskeleton is the bones and muscles of the cell to move it around and move organelles around inside of it. The cytoskeleton may even provide a “road” or “monorail” within the cell for organelles to travel along. One kind of organelle that travels throughout the cell is a lysosome. Lysosomes are the clean-up crews that destroy old parts of the cell or things that do not belong in the cell. To perform their tasks, as well as many other tasks performed within the cell, energy is needed. Mitochondria provide energy for the cell as a type of “power plant.” Every cell has at least one mitochondrion. Mitochondria and all the other parts work together to sustain the life of a cell. Studying how these parts are affected by spaceflight opens up new doors of research and gives us an exciting look into the cell.

CHEMISTRY – PROPERTIES OF MATTER

Understanding properties of matter is an integral part of chemistry. Properties such as density, melting point, boiling point, and solubility vary from one substance to another and can help us to distinguish between them. Maybe you have noticed a bottle of salad dressing with oil and vinegar. The oil sits on the top of the vinegar and water solution because the oil is less dense. Or maybe you have seen the hot air rising off the pavement on a sunny day. Hot air is less dense than cool air so it rises. Hot air is more buoyant than cool air.
The property of density causes buoyancy driven convection when a lower density is below a higher density. Fluids, including gases, that are more dense fall through less dense fluids due to gravity. One event in nature where this happens is a tornado. In spaceflight, objects are all in free-fall so fluid densities are not affected by buoyancy driven convection. Therefore, they float together and usually in a spherical shape because of surface tension. Surface tension is overwhelmed on earth because of gravity, but in space, it has a relatively strong effect. Surface tension is a property of liquids that comes from molecules’ tendency to “stick” to one another with cohesive forces. Because the molecules on the surface are not surrounded by other similar molecules, their cohesive forces are directed inward and act like a type of elastic skin.

Another set of properties determine when a substance changes from a solid to a liquid, a liquid to a gas, or vice versa. The temperature where a substance changes from solid to liquid is the same temperature when that liquid changes to a solid. These are called the melting and freezing point but again, they are the same temperature. A substance changes from a liquid to a gas and back from a gas to a liquid at the boiling and condensation point.

We can also look at how substances dissolve within one another. A liquid or solid that dissolves into a liquid, like salt into water, is said to be “soluble” in water. If a liquid or solid cannot dissolve in a liquid, it is “insoluble.” If a substance is “hydrophobic,” it is afraid of water or will not mix with water – “hydro” = water and “phobic” = fear. “Hydrophilic” means that a substance likes water or will mix with it. We take advantage of the hydrophobic property of a particular liquid to create beads in some cell cultures. Some cells are “adherent” meaning they need to cling to something to grow. Using drops of a hydrophobic liquid, the drops form spheres that are perfect for cell culture in the bioreactor.

Understanding everyday properties of matter gives scientists “tools” to solve problems in research. By testing and utilizing these properties in spaceflight, our findings are all the more interesting. I am very excited for the future of space research and hope to see you following along in our footsteps one day.

PHYSICS

As you might imagine, physics play an integral part in space research. Understanding how microgravity is achieved is very often misunderstood, however. So, let us talk about gravity, orbits, energy, and forces. First of all, why do objects "float" while in space? Terms used to describe this include: weightlessness, free-fall, and microgravity. Many people think that because an object, such as the Space Shuttle or International Space Station (ISS), is so distant from earth (120-360 miles) that gravity has no effect on them. Although, if gravity has no effect on them, they would not be held in orbit but continue traveling in a straight line away from earth. The Space Program is not quite ready to send people off like that. Also, realize that the moon, 240,000 miles away, is held in orbit around the earth due to earth's gravitational pull. It is true that the further one travels from earth, the less gravitational pull they will experience. If there was a tower 120-360 miles high, a person standing on a scale at the top would weigh about 85-95% of their weight as compared to the earth's surface. For an object to actually escape earth's gravity, it has to travel fast enough to reach "escape velocity," or 25,000 miles/hour.

Now, think of sky divers. Disregarding air resistance, they are in free-fall. If they jump from an airplane, sky divers are moving forward with the plane and fall in an arcing path. What if the speed of that plane was fast enough to make the arc of their path equal to the curve of the earth's surface? On launch, the Space Shuttle arcs over to travel horizontal with the ground. At approximately 17,500 miles/hour, the velocity in the horizontal direction balances the pull of gravity keeping an object in orbit. This is "orbital velocity." Objects actually look like they are floating because they are falling around the earth continually. This is termed "microgravity" generally meaning "a very small amount of gravity."

Orbits can be the shape of a circle or an ellipse where the earth is the center or a focus. If an orbit is elliptical in shape, it has a perigee (nearest point) and an apogee (away; furthest point). When the perigee and apogee are equal, the orbit is circular. When the Space Shuttle meets to dock with the ISS, it has to change its orbit several times. First, it attains a circular orbit well below the ISS. Second, the Shuttle boosts into an elliptical orbit where the perigee is the same distance from earth as the first, circular orbit, and the apogee is the same distance as the circular orbit of the ISS. When the Shuttle is at its orbital apogee, it boosts again to increase its orbital energy again and obtain the circular orbit of the ISS.

The rotating wall vessel (RWV) bioreactor also shows similar orbital behavior when used on earth. The RWV is a tool for simulating some of the effects of spaceflight on cells. Cells rotate in a circular "orbit" when rotated at their optimum speed. If rotated too fast, cells cling to the sides of the bioreactor. If they rotate in an ellipse, they do not have enough energy to rotate in a circle and must be sped up. Gravity's effect is apparent in an elliptical rotation when cells fall quickly over the center and barely have enough energy to round back over the top. Turning the cells in the bioreactor makes them fall continuously and tumble randomly and therefore randomizes the effect of gravity on them.

By bringing objects into the microgravity environment of spaceflight, they escape many conditions that are experienced on earth. Gravity causes fluids of higher density to sink and lower density to rise. This is called "buoyancy driven convection" and overpowers many other effects such as diffusion. In free-fall, fluids mix regardless of their different densities. Diffusion occurs without the hindrance of gravity as particles disperse evenly. Surface tension holds liquids in spheres to create the least amount of surface area for the liquid's volume. These forces are allowed to dominate in free-fall environments created by spaceflight, drop towers, sounding rockets, and bioreactors. I hope you now have a better grasp of spaceflight and why space research is so important for our future.